Occurrence of the eucalypt leaf beetle, *Cadmus excrementarius* Suffrian (Coleoptera: Chrysomelidae: Cryptocephalinae), in Western Australia

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Abstract

The chrysomelid beetle *Cadmus excrementarius* has recently been observed as a pest in south-western Australian blue gum (*Eucalyptus globulus* ssp *globulus*) plantations. The insect was first recorded from Western Australia in 1904 and has since been found at over 30 different locations in the State. Seven host species from the genera *Eucalyptus* and *Corymbia* have been recorded in Western Australia. Most records of *C. excrementarius* adults were in the months of January to March. The insect mainly occurs on blue gums in the area bounded by the jarrah (*Eucalyptus marginata*) forest, where it may persist on flooded gum (*Eucalyptus rudis*) and to a lesser extent marri (*Corymbia calophylla*). *E. marginata* appears to be a less preferred host for *C. excrementarius* beetles, because its leaves were significantly less consumed than those of *E. rudis* and *C. calophylla*. Some observations on the natural history and predators of this beetle are presented.

Keywords: *Cadmus excrementarius*, beetle, Chrysomelidae, Cryptocephalinae, eucalypt, blue gum plantation, pest, jarrah forest

Introduction

Chrysomelid beetles are recognised as one of the most serious insect problems associated with fast-growing eucalypt plantations in several Australian states, due to the propensity of these insects to feed on newly expanded foliage (Elliott *et al.* 1998). Feeding damage to the new season's foliage often leads to the characteristic 'broom-topped' appearance of trees resulting from removal of the apical crown. Extreme levels of defoliation by chrysomelids have been shown to cause significant reductions in tree height, diameter and volume, and also potential growth malformation (Candy *et al.* 1992; Elliott *et al.* 1993; Elek 1997).

The cryptocephaline chrysomelid, *Cadmus excrementarius* Suffrian, was first reported in Tasmanian blue gum, *Eucalyptus globulus* ssp *globulus*, plantations in south-western Australia by Abbott *et al.* (1999), during their study of canopy arthropod faunas that was carried out between 1993 and 1994. It was not initially regarded as a serious pest, but it is now one of the major chrysomelid pests of Tasmanian blue gum plantations in south-western Australia (Loch & Floyd 2001). Only the adult stage of *Cadmus* species feeds on eucalypt leaves; the larval stage lives on the ground in an ovoid case made of faecal matter, and feeds on litter and recently fallen leaves (Reid 1999a, b). The congeneric beetles, *C. crucicollis* (Boisduval) and *C. nothus* Lea, occur in the jarrah forest (Abbott 1995) and have also been collected from Tasmanian blue gum plantations in south-western Australia, although they are much rarer than *C. excrementarius* (AD Loch, unpublished data).

An understanding of the ecology and behaviour of *C. excrementarius* is critical if this pest is to be managed effectively. The purpose of this paper is to report on the geographic and temporal distribution of this species in south-western Australia. Some observations on natural history, natural enemies and host range are also made. A further paper reports on its pest status in Tasmanian blue gum plantations (dos Anjos *et al.* 2002).

Materials and methods

Field trips throughout south-western Australia were conducted by NDA between January and November 2001, during which searches were undertaken for *C. excrementarius* adults and larvae in both blue gum plantations and native forests. Insect collections were also inspected in the Western Australian Museum, WA Department of Conservation and Land Management, WA Department of Agriculture, and Curtin University of Technology. Records of *C. excrementarius* were also supplied by C A M Reid (Australian Museum), and taken from scientific papers and from unpublished data provided by ADL. All records were geocoded and a map showing the species' geographic distribution throughout Western Australia was prepared using Range Mapper® V 2.0. In addition, the host, year and month of capture of all records were noted.

An experiment was conducted under field conditions in a blue gum plantation at Rocky Gully (34° 32' S, 117° 01' E) to examine whether there was any feeding preference between the three principal native tree species in the region and blue gum. A single, newly expanded, undamaged leaf of either blue gum, flooded gum, *Eucalyptus rudis*, marri, *Corymbia calophylla*, or jarrah, *Eucalyptus marginata*, was removed and inserted in a

series of 150 ml vials filled with fresh water (n = 14 for each species). One female beetle was confined to the leaf by means of a plastic mesh sack that was clipped around the top of the vial. The leaves were exposed to the beetles for 48-hours from March 1 2001, and were then removed and stored in cool, moist conditions. The leaf shape was subsequently traced on green tissue paper and the shape of the undamaged leaf was recreated. The surface area of the paper model and the leaf remains were then measured using a Macintosh® computer scanner and the amount of leaf area eaten was determined by calculating the difference in the two areas. The leaf area of each tree species that was consumed by one female beetle was then compared by one-way ANOVA and differences between means were assessed using Duncan's multiple range test.

Morphological and behavioural aspects of each biological phase were noted, both under field conditions at Rocky Gully and in the glasshouse at Curtin University, Perth. Larvae were maintained in the glasshouse in an 80x40x40 cm glass tank filled with sandy soil, jarrah litter, and blue gum seedlings. Larvae collected from the field in April and June were also reared in petri dishes; they received fresh leaves three times a week. Field observations on larvae and observations on adult feeding, mating, oviposition and natural enemies were carried out throughout 2001. From 2-4 March 2001, ten wooden plates (10x10 cm) were placed on the ground at 10 m intervals inside both the Rocky Gully blue gum plantation and jarrah forest. Twenty egg scatoshells (eggs encased in faecal material) were then placed on each plate for 48 hours to observe predators. Plates were inspected every 2-3 hours during both day and the evening, and predators were collected.

Figure 1. Sites from which *Cadmus excrementarius* (•) has been collected in Western Australia. The thick line shows the boundary of the jarrah forest region (after Dell & Havel 1989).

Results

Geographic distribution in Western Australia

C. excrementarius was recorded at over 32 different sites in south-western Australia, ranging from latitudes 30° 22' S to 34° 58' S and from longitudes 115° 38' E to 123° 52' E (Fig 1). All but five of the sites were within the jarrah forest region. The exceptions were the Kalannie, Balladonia, Borden, Dumbleyung and Broomehill records, which were from eucalypt woodlands.

Temporal distribution in Western Australia

Adults of *C. excrementarius* were first collected in South Perth and Denmark at the beginning of last century, after which there were no records for about 60 years. Increasing numbers of records of this species started to appear in the early 1990s (Fig 2). More than 80% of the new records were made in 2000 and 2001, and more than half (53%) were in 2001. *C. excrementarius* adults have only been collected in Western Australia between December and June. Most adult records (87%) were for January, February and March, with more than half (57%) from February.

Host plants

C. excrementarius has been recorded from seven host species from the genera *Eucalyptus* and *Corymbia* in Western Australia. These include Tasmanian blue gum, jarrah, marri, WA flooded gum, tuart (*E. gomphocephala*), Dundas mahogany (*E. brockwayi*) and oil mallee (*E. kochi*). Host age was only known for *E. g.* ssp *globulus*, which varied from 6 months to 5 years, with more cases (71%) on trees in the first to fourth years of age. *C. excrementarius* has also been recorded from *E. largiflorens* near Swan Hill, NSW.

Feeding preference

The area of leaves consumed by *C. excrementarius* beetles differed significantly for *E. rudis*, *E. g.* ssp. *globulus*, *C. calophylla* and *E. marginata* ($F_{3,47}$ = 3.57, P = 0.02). Mean area consumed was 318.67 mm² (n = 13) for *E. rudis*, 292.37 mm² (n = 14) for *E. g.* ssp *globulus*, 239.83

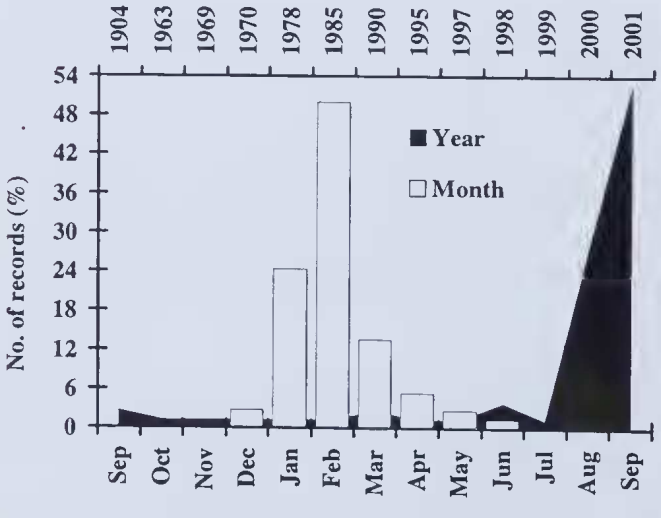

Figure 2. Collection records (months and years) of adult *Cadmus excrementarius* in Western Australia.

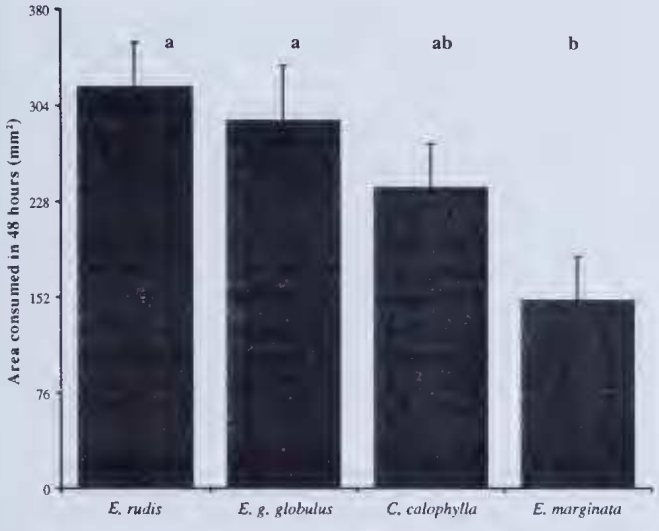

Figure 3. Mean (± se) leaf area consumed by single *Cadmus excrementarius* females on four different tree species. Means annotated with different letters are significantly different from each other ($P < 0.05$ by Duncan's multiple range test).

mm^2 (n = 14) for *C. calophylla*, and 150.30 mm^2 (n = 11) for *E. marginata*. Amounts of *E. rudis* and *E. g.* ssp *globulus* consumed were similar but significantly greater ($P < 0.05$) than that of *E. marginata*. *C. calophylla* was intermediate in this regard (Fig 3).

Natural history

C. excrementarius adults generally begin appearing in plantations during late December and January (ADL, unpublished observations), but under warmer greenhouse conditions in this study they started to emerge in November. Before emerging from its faecal case, the adult gnaws a circular opening to escape. They mostly exit the case in the morning, when day temperatures are increasing. Observations on larvae in petri dishes indicated that males started to emerge one day before females. One male can mate with more than one female, and females can copulate with two or more males during the same day. Duration of mating was 31.9 ± se 1.5 minutes (range 16-55 minutes, n = 17). Females started laying eggs the following day and produced 17.8 ± se 1.3 eggs $female^{-1}$ day^{-1} (range 2-54, n = 24). Eggs were produced during day and night over several days, with a cumulative production of between 8 to 168 eggs per female (n = 6) over 9 days of laboratory observation.

Under field conditions, female beetles fed voraciously, stopping regularly to lay eggs and coat them with faecal residues; males tended to mate and then rest, spending little time feeding. The egg of *C. excrementarius* is yellow, oblong (1.1 ± 0.02 mm long and 0.4 ± 0.02 mm diameter; n = 24), has a soft chorion, and is encased in a rough brownish scatoshell. Newly built scatoshells are 1.7 ± 0.05 mm long and 1.1 ± 0.01 mm diameter (n = 35). Scatoshells are dropped on the ground beneath trees where the female feeds. Simulated rain in the glasshouse colony indicated that eggs hatch about 3 days after contact with moisture.

During the egg stage, scatoshells were frequently removed by ants, which took them to their nests. In the blue gum plantation, 47.5% (range 5-100%) of egg scatoshells were removed by ants, while in the jarrah forest only 6% (range 0-20%) were removed. Ants removing egg scatoshells in the blue gum plantation were *Rhytidoponera metallica* (F Smith) and *Pheidole ampla perthensis* Crawley, whereas those in the jarrah forest were *Rhytidoponera violacea* (Forel), *Monomorium sordidum* Forel, *M. sydneyense* Forel, and *Iridomyrmex chasei* Forel.

The egg scatoshell is retained as a case after the larva hatches, as in all Cryptocephalinae (Reid 1999a), and builds up with faecal residues as the larva grows. Full-grown cases may be 11.3 ± 0.2 mm long and 5.2 ± 0.1 mm wide (n = 32). Larvae feed gregariously on decaying leaves and other litter components, such as bark and twigs. Under glasshouse conditions, they will also feed on fresh leaves. Under moist conditions in the field, larvae were seen climbing on the basal part of saplings to feed on live leaves, but under dry soil conditions the larvae remained in groups (1-28, n = 46) under decaying leaves. In addition to being found in blue gum plantations, larvae were observed feeding on decaying leaves underneath *E. rudis*.

Before pupation, the larva inserts the opened side of the case into the ground and fixes part of the case inside the soil. It then blocks the case entrance with faecal residues and turns its head back to the upper side of the case before pupation. The exuvium is released on the bottom of the case. Under glasshouse conditions, larvae stopped feeding during 15-21 October 2001 and adults started emerging on November 22 2001. In petri dishes, they stopped feeding between 5-11 November 2001, and adults started emerging on December 6 2001. The pupal period is approximately 4 weeks in duration.

Under glasshouse conditions, pupae were attacked by fungus and mites (Pyemotidae), which sometimes killed the insects. Under field conditions, adult beetles were preyed upon by bugs (Reduviidae) and by a small spider (Theridiidae).

Discussion

C. excrementarius is extremely widespread in semiarid/arid southern Australia from Cunnamulla, Qld through NSW, VIC, SA to south-western WA (C A M Reid, Australian Museum, personal communication). However, in WA *C. excrementarius* appears to be generally distributed in forested areas under a Mediterranean climate. The records from Kalannie, Balladonia, Borden, Dumbleyung and Broomehill, indicate the presence of outlying populations of *C. excrementarius* in woodland or mallee areas. If this species is more widespread in WA than indicated by current records, it may be because of lower levels of collecting in other parts of Western Australia.

In south-western Australian blue gum plantations, *C. excrementarius* tends to be concentrated from Boyup Brook through to the east of Albany, where plantations are interspersed between fragments of jarrah forest. As all records of *C. excrementarius* in blue gum plantations were for sites inside jarrah forest, proximity of plantations to native forest could be a contributing factor

to this problem, as suggested by Abbott *et al.* (1999) and discussed by Loch & Floyd (2001). The increased frequency of *C. excrementarius* collections in the last 2 years mainly reflects increased collecting intensity in blue gum plantations in south-western Australia. In addition, the rapid rise of the blue gum plantation industry has been associated with a corresponding increase in *C. excrementarius* occurrence, as it has with other insect problems (Loch & Floyd 2001).

E. marginata appears to be a less preferred host for *C. excrementarius* beetles, because its leaves were significantly less consumed than those of *E. rudis* and *C. calophylla* (see Fig 3). Similarly, Hall (1992) found distinct preferences of other chrysomelids for *E. rudis* and *C. calophylla*, rather than *E. marginata*. This is consistent with Majer & Recher's (1988) observation of significantly lower invertebrate populations on *E. marginata* than on other tree species. The jarrah forest is dominated by *E. marginata* and *C. calophylla*, with some areas of *E. rudis* and other species (Dell & Havel 1989). According to this study, *E. rudis*, whose leaves have higher concentrations of nitrogen, phosphorous and potassium (Abbott *et al.* 1993), appears to be the most favoured native host in the jarrah forest and could be the main source of *C. excrementarius*. To a lesser extent, *C. calophylla*, and other eucalypt species could also harbour populations of this beetle. Another important reason to expect pressure on blue gum plantations is the period of adult *C. excrementarius* activity (Fig 2), which coincides with the dry season in south-western Australia. At this time of the year, native eucalypts have few fresh or tender shoots but blue gum saplings, which grow vigorously at this time of year, are highly suitable as an alternative food source. This could be a further contributing factor to the incidence of this pest in south-western Australian blue gum plantations.

Eggs are typical of Cryptocephalinae beetles (Erber 1988) and are preyed upon by a group of ants, which are known seed collectors; possibly these ants are mistaking the eggs for seeds. Sites inside the plantation seem to exhibit more egg predation and by different species of ants than those inside the jarrah forest. Larvae of this species, and other Cryptocephalinae, may also be killed by fungi and mites (C A M Reid, Australian Museum, personal communication).

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